Atomic Energy Control Board
P.O. Box 1046
Ottawa, Canada
K1P 5S9

Commission de contrôle de l'énergie atomique
C.P. 1046
Ottawa, Canada
K1P 5S9

INFO-0248(E)

USE OF BIOLOGICAL INDICATORS FOR EVALUATING ENVIRONMENTAL STRESS

by

C. Létourneau and J. Castonguay

Atomic Energy Control Board
Ottawa, Canada

September 1988

Canada

Report

ABSTRACT

Le présent rapport examine l'utilité des analyses biologiques pour évaluer le stress environnemental. Toutes les formes de stress sont abordées dans ce rapport; une attention particulière est portée toutefois à l'utilisation des analyses biologiques pour évaluer l'impact des rejets radioactifs de l'industrie nucléaire sur l'environnement. D'abord, nous examinerons les différentes analyses biologiques qui sont regroupées en deux approches : l'approche holistique (indices biotiques et de diversité) et l'approche réductionniste ("indicateur biologique" proprement dit). Puis, nous examinerons le potentiel indicateur des végétaux et des animaux, basé sur les critères établis.

Le rapport se termine par une série de lettres reçues de différentes organisations qui cernent bien l'emploi actuel au Canada des indicateurs biologiques pour évaluer le stress environnemental.

ABSTRACT

This report examines the usefulness of biological analyses for evaluating environmental stress. All forms of stress are addressed; particular attention, however, is paid to the use of biological analyses to evaluate the impact on the environment from radioactive releases of the nuclear industry. First, we will review different biological analyses which are grouped into two approaches: the holistic approach (biotic and diversity indices) and the reductionist approach ("biological indicators" per se). Secondly, we will compare the usefulness of plants and animals as indicators based on the established criteria.

This report ends with a compilation of letters received from different organizations which outline the present usage in Canada of biological indicators for evaluating environmental stress.

(Aussi disponible en français.)

TABLE OF CONTENTS

	PAGE
ABSTRACT	i
List of figures	iii
List of tables	iv
INTRODUCTION	v
Part 1 - General considerations on the methods used to measure the environmental impact of human activities	1
1.1 Biological and physico-chemical methods	1
1.2 Types of biological methods	1
1.2.1 Biotic indices	2
1.2.2 Diversity indices	4
1.2.3 Biological indicators (BI)	5
Part 2 - Plant and animal biological indicators	8
2.1 Plant biological indicators	8
2.1.1 Aquatic plant BIs (phytoplankton, macroalgae and riparian plants)	8
2.1.2 Terrestrial plant BIs (lichens and mosses, trees and other plants, special case: Tradescantia)	9
2.2 Animal biological indicators	11
2.2.1 Aquatic animal BIs (zooplankton, macroinvertebrates, fish)	11
2.2.2 Terrestrial animal BIs (invertebrates, amphibians and reptiles, birds, mammals)	13
CONCLUSION	13
REFERENCES	15
APPENDIX A - Advantages and disadvantages of selected plants as BIs	22
APPENDIX B - Advantages and disadvantages of selected animals as BIs	27
APPENDIX C - Glossary	33
APPENDIX D - Letters from various organizations describing their use of BI methods	35

LIST OF FIGURES

PAGE

Figure 1: Diagram of the approaches characteristic of biological methods 7

LIST OF TABLES

PAGE

Table I: Biological indicator selection criteria 14

INTRODUCTION

The purpose of this report is to examine the possibility and validity of using biological organisms as indicators of environmental stress in the same way that animals become restless in case of fire or canaries placed in a mine warn of danger by succombing to asphyxia. We culled the literature to find similar biological indicators (BI) in both the animal and the plant kingdoms.

Physical and chemical methods are currently the most common approaches for environmental analysis at industrial facilities. But given a number of weaknesses in these analytical methods, research has been undertaken to find an alternate, if not complementary, method. We will begin by reviewing various biological analyses, which are classed according to two approaches, i.e., the holistic approach (biotic and diversity indices) and the reductionist approach (biological indicators per se). We will then explore the indicator potential of plants and animals in light of established criteria.

Given the extremely broad scope of the subject at hand, this report is merely a brief overview intended to introduce the novice to biological methods as tools for the measurement of environmental stress. It should be noted that the expression "environmental stress" is used here to designate all types of contamination, be they due to organic substances, heavy metals, hydrocarbons or other chemical, thermal or radioactive substances. Special emphasis is placed on the use of biological analyses to evaluate the environmental impact of radioactive effluent from nuclear power plants. Consequently, Atomic Energy Control Board licence-holders will find this report useful upon choosing samples for their environmental monitoring programs.

This report includes a glossary that will help non-biologists understand the scientific terms flagged with an asterisk in the text.

PART 1

GENERAL CONSIDERATIONS ON THE METHODS USED TO MEASURE THE ENVIRONMENTAL IMPACT OF HUMAN ACTIVITIES

1.1 Biological and physico-chemical methods

The use of chemical analyses alone is insufficient for the precise assessment of environmental impact. This is pointed out up by the following observations (Phillips 1977a):

1. Samples are collected at one spot at one specific time (localized data) and therefore provide no information on extreme variations in the environment.

2. Variations elicited by numerous factors, including season, depth, currents and tides, complicate comparison among different sampling sites.

3. Contaminants present in trace concentrations are frequently difficult to detect and measure.

4. The measurement techniques, which are often labourious and require extensive manipulation, increase the risks of contamination of the samples.

5. The chemical form associated with the toxicity of the contaminant is often difficult to determine.

To point out the inefficiency of using chemical analyses alone, we can cite a study by Patrick (1949, in Worf 1980). The study in question, focusing on the Conestoga basin, involved chemical and biological sampling. Based on the biological data, 23 rivers were polluted, but one-fourth of them showed no chemical contamination. Thus chemical analysis of the samples did not portray the real environment of the living organisms present in these rivers.

If chemical analysis is to yield representative results, water samples must be collected on a virtually continuous basis at many different stations. Moreover, analytical methods must be greatly improved. These conditions inevitably entail considerable expense. To alleviate the problem, biological methods have frequently been recommended to round out chemical data by providing a more specific aggregate picture of the impact which the contaminants have on the environment.

1.2 Types of biological methods

Studies on biological methods are characterized by two approaches, i.e., the reductionist approach and the holistic approach (Beaulieu 1982). The first focuses on individuals, the second on communities of live organisms. The holistic approach proposes a comprehensive view of the environment, putting the priority on study of the aggregate ecosystem. This entails labourious, costly studies. The reductionist approach, which involves less expense and yields rapid results, is sometimes preferred by environment managers, who always deal with well-defined, short-range matters. The dilemma concerning these two schools is resolved only by considering

the purpose of the studies. Are they short-term efforts calling for only a sketchy view of the problem and aimed at obtaining rapid results? Or are they longer-term, more comprehensive projects?

Both approaches encompass three main types of biological methods: biotic indices, diversity indices and biological indicators. The first two types examine communities of organisms, the first in qualitative terms and the second in quantitative terms. In short, these are holistic methods. The third type, which is the subject of this report, focuses on the individual (reductionist approach) from both the qualitative and quantitative perspectives (Figure 1).

The nature, use and advantages, as well as the disadvantages, of these three types of methods are briefly described in the next sections.

1.2.1 Biotic indices

Biotic indices are used to qualify community structure according to a scale chosen at random and are generally based on the presence or absence of different species. There would appear to be almost as many indices as there are researchers, who develop scales suited to their own particular studies. Still, there are a number of major indices, i.e.:

1.	Saprobic index	Kolwitz and Masson 1908 * Gauffin and Tarzwell 1952-1956 * Beck 1954-55 * Pantle and Buck 1962 * Liebmann 1962 · Fjirdingstad 1965 · Sladecek 1965 · * in Kaesler et al. 1974 · in Pesson 1976
2.	S.C.I. (sequential comparison index)	Simmons and Reed 1973 Cairns et al. 1976
3.	Trent biotic index	Woodwiss 1964, in Hargreaves et al. 1979
4.	Chandler biotic index	Chandler 1970, in Hargreaves et al. 1979
5.	Patrick method	Patrick 1949, in Worf 1980
6.	Biotic index	Verneaux 1966 * Verneaux and Tuffery 1967 * Costa 1974 * * in Pesson 1976

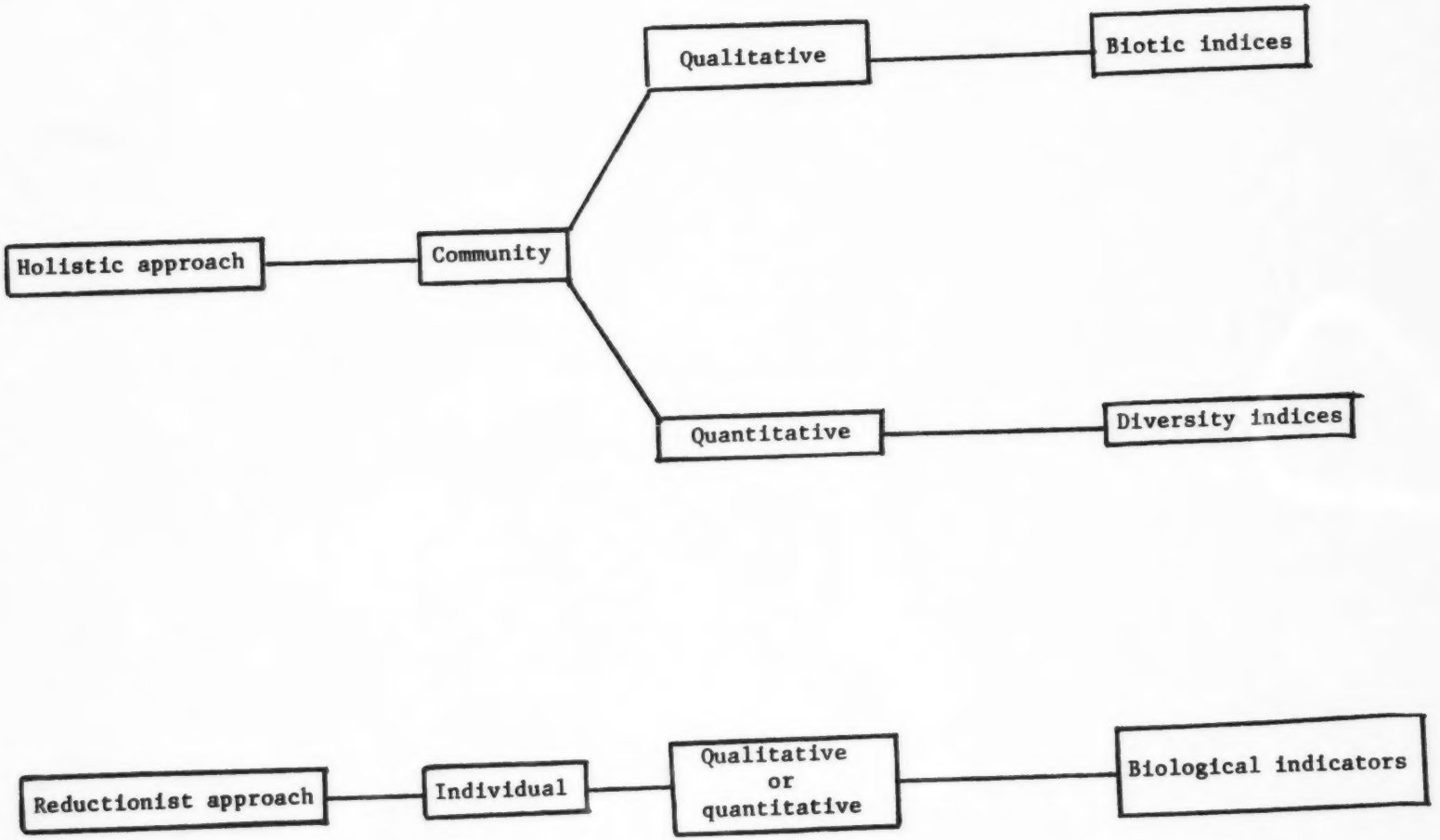

Figure 1 - Diagram of the approaches characteristic of biological methods.

These methods have often drawn criticism directed at

1. subjectivity at the time of classification;

2. the fact that identification of the species is sometimes difficult and requires special expertise;

3. poor understanding of the ecology;

4. inattention to relationships between species;

5. inattention to the individuality of each habitat (Murphy 1978);

6. the fact that validity is limited to organic contamination (Krishnamortti et al. 1978).

Biotic indices should therefore be interpreted with caution. Still, these methods are useful in certain situations.

1.2.2 Diversity indices

While biotic indices are basically qualitative, diversity indices quantify the sampling data. Numeric parameters (e.g., number of individuals and of species, ratio, abundance and relative frequency) are established to evaluate environmental stress.

Here are the main diversity indices:

1.	Shannon-Weiner index	Margalef 1958 * Wilhm and Dorris 1968 * Buzas 1972 * * in Kaesler et al. 1974
2.	Fisher index	Fisher et al. 1948, in Dajoz 1975
3.	Gleason diversity index	Word et al. 1977
4.	Bray-Curtis index	Rabeni and Gibbs 1977, in Nalepa 1979

These methods were first employed in North America (Cook 1976) and then rapidly spread throughout the world scientific community. Despite their widespread use, these methods have often been challenged or even rejected by many authors, who cite a number of key concerns.

1. In theory, increased diversity of the species should lead to increasing stability (Margalef 1968 and MacArthur 1955, in Word 1980). But this is not always borne out experimentally (McNaugton 1968 and Hurd et al. 1971, in Worf 1980).

2. Diversity indices are sometimes insensitive to changes in the species composition of communities (James 1979, in Fowler 1980).

3. The use of diversity indices requires frequent sampling to gather information on the life cycle of the dominant organisms.

4. Diversity indices are valid only for organic contamination. Unlike with organic contamination, environmental stress induced by an inorganic contaminant brings about a decline in both the number of individuals and the number of species, making diversity indices difficult to interpret (Persoone and Pawn 1979; Cairns Jr. in Worf 1980).

Despite these shortcomings, diversity indices are used to study the dynamics of the ecosystem and can aid in understanding the results obtained from chemical as well as biological analyses.

1.2.3 Biological indicators

Unlike the foregoing methods, biological indicators focus on the individual and prove useful for examining environments stressed by inorganic contamination. The usefulness of these indicators lies in the observation of variations in the abundance, morphology, physiology or behaviour of a particular species, which variations reflect environmental disturbances.

Four factors argue in favour of the use of biological indicators:

1. Biotic and diversity indices comprise many disadvantages, including inefficient data interpretation in cases of inorganic contamination.

2. The study of entire communities is labourious and costly.

3. Kaesler et al. (1974) observed that the analysis of entire ecosystems was redundant in several respects. In Kaesler's study, the information gathered from the analysis of Gastropoda* closely matched that provided by the other organisms, i.e., bloodsuckers, Amphipoda,* Decapoda* and bivalves. Thus the information collected using the holistic approach does not justify the amount of work involved.

4. The results might be more detailed if only one species were studied.

In sum, biological indicators are an interesting option. They have been taken from both the plant and the animal kingdoms in terrestrial and aquatic habitats (it is noted, however, that it is the aquatic organisms that are chosen most often as biological indicators).

But like the foregoing methods, the BI method has not escaped criticism.

1. In many cases, long-term biological changes must occur before the effects of contamination can be seen (Turoboysi in Alabaster 1977).

2. Experts are sometimes required for taxonomic classification.

3. The response of an organism to stress is not necessarily specific to one contaminant, making it difficult at times to pinpoint the link between cause and effect.

Over the years, experiences with BIs have refuted such criticism. For example, a plant that responds rapidly and selectively to radioactivity has been discovered (see 2.1.2). While this type of indicator is rare, further research might uncover similar BIs.

How does one choose a biological indicator? Definitions have been proposed by many authors (Word et al. 1977, James and Evison 1979, Cairns in Worf 1980). The following definition encompasses all of them:

A biological indicator (BI) is an animal, plant or microbial SPECIES wherein ALL the LIVE organisms reflect disturbances in the aquatic or terrestrial environment in the same way through variations in abundance, MORPHOLOGY, PHYSIOLOGY or BEHAVIOUR and meet the established SELECTION CRITERIA.

Some key terms in this definition merit further explanation.

SPECIES: BIs must be identified by species, for different species of the same genus may respond differently to the same environmental stress (Resh and Unzickep 1975).

ALL: It must be verified that all the organisms vary in the same manner. In case of differences resulting from genetic factors, the species cannot be regarded as a valid BI.

LIVE: It must be verified that the specimens are alive at the time of sampling to ensure that the sampled organisms reflect the environment which they are supposed to represent.

MORPHOLOGY: Variations of this type may involve changes in colour, hair growth, formation of tumours, etc.

PHYSIOLOGY: Variations of this type may involve changes in breathing and cardiac rates, kidney function, etc.

BEHAVIOUR: Variations of this type may involve changes in reproductive behaviour, evasion of hostile environments, abnormal movements, etc.

SELECTION CRITERIA: a BI must meet certain conditions to be considered acceptable. Many authors have set criteria based on their studies (Foulquier and Grauby 1974, Wielgolaski 1975, Phillips 1977a, Sankar et al. 1978, and Fowler 1980). These criteria are listed in Table I. They obviously define the ideal biological indicator and are not all applicable in every situation. As we will see in part 2, these criteria will determine the advantages and disadvantages of the various taxonomic groups as regards the choice of a BI.

TABLE I

BIOLOGICAL INDICATOR SELECTION CRITERIA

CLASS	PRACTICAL CRITERIA	ECOLOGICAL CRITERIA
Class 1		
Required criteria	. Easy sampling . Taxonomic key* available: easily identified . Rapid results . Response of organism must be easily measured	. Abundant presence . Representative of the environment
Class 2		
Preferred but not required criteria	. Laboratory conservation (a) for defecation if desired (b) in vivo experimentation	. Accumulation of toxin without dying . Long life (>1 year) . Stenovalent . Role in human food chain . High concentration factor of pollutant under study . Known physiology and ecology
Class 3		
Ideal criteria but difficult to require	. Simple correlation between the concentration of the contaminant in the organism and in the ambient environment	. Ubiquist* . Specific responses to specific contaminants (selectivity) . Strong indicating capacity

PART 2

PLANT AND ANIMAL BIOLOGIAL INDICATORS

In this part we will analyse the taxonomic groups that provide species serving as BIs. Both the plant and the animal kingdoms comprise species that can be used to assess environmental stress. This report includes comparative tables describing the advantages and disadvantages of using given taxonomic groups and giving examples of specific studies (appendices A and B).

2.1 Plant biological indicators

Plants can be excellent biological indicators. Unlike animals, plant species absorb nutrients through their physical structures, e.g., leaves, stems and roots.

We will examine the characteristics of the aquatic and terrestrial taxonomic groups in search of potentially valid biological indicators.

2.1.1 Aquatic plant BIs

Phytoplankton

Phytoplankton is a group of microscopic plant organisms lacking means of locomotion and more or less drifting with the current. Situated at the base of the food chain, it serves as food for zooplankton, mollusks and fish.

Phytoplankton can be used as an indicator of environmental stress. But diversity indices are preferred for the study of phytoplankton responses to disturbance of an environment strongly affected by organic or thermal contamination. Still, the classes of phytoplankton most commonly used as BIs are diatoms, green algae and blue-green algae (Kinsbury and Rees 1978). In the past microalgae have been used mostly for toxicity studies, which have the advantage of being short term and serve as studies preliminary to more intensive investigation. Such experiments make use of certain species recognized as excellent contamination indicators owing to their sensitivity. Consequently, these biological tests are generally more sensitive than chemical tests. On the other hand, they pose the problem of non-extrapolation in *in vivo* environments.

Macroalgae

Macroscopic algae inhabit the shallow sumberged areas along water-courses.

Certain species in this group are excellent accumulators of various chemical substances. Their sedentarity, fairly easy sampling and great abundance favour them when it comes to selecting a biological indicator for a long-term environmental monitoring program.

Brown algae have been used chiefly to trace heavy metals (Lambinon et al. 1976). Certain species yield fairly rapid results and are suitable for short-term studies.

Riparian plants

This section deals with aquatic bryophytes and phanerogams.* Bryophytes are represented by hepatics* and mosses per se. These organisms settle on dikes, sluice gates, iron-works and dam masonry and under bridges and flood gates, in other words, man-made semi-natural environments. Bryophytes have a rudimentary physical structure without stems or leaves, which favours the integration of substances from the environment throughout the body. These organisms feature a very slow growth rate and a high concentration factor, making analysis of long-term variations in concentration very worthwhile. Phanerogams, which are more highly evolved organisms, represent the transfer zone between aquatic and terrestrial environments.

These plant species have been neglected in the past, not because they were seen as a group that could not provide good BIs but because there is very little information about them. Of what information exists, we can refer to long-term studies conducted on the Meuse River in Belgium. A coefficient calculated from the different habitats of the species, their tolerance and their capacity to concentrate certain substances can be used to map the watercourse and compare the state of certain areas. Reports have also cited the usefulness of phanerogams in evaluating the concentration of heavy metals. There is, for one, a population of Posidia oceanica, a marine phanerogam, which has been used to detect mercury contamination in the Mediterranean. The extreme sensitivity and large population of this organism make it an excellent infralittoral biological indicator (Augier et al. 1977).

2.1.2 Terrestrial plant BIs

Plants have been used mainly to assess atmospheric contamination, although a few examples can also be found for soil contamination (absorption of toxins through the radicular system).

Lichens and mosses

Lichens lack a foliar or radicular system; the absence of a cuticle* or stoma* allows the absorption of nutrients and gases throughout the body. Their slow growth and inability to eliminate toxins make them excellent biological indicators (Varshney and Garg 1979). Lichen is a plant organism consisting of an alga and a fungus living in symbiosis. It develops on a given substrate (bark or stone), from which it derives certain nutrients. Mosses inhabit more humid environments than do lichens.

This group provides for excellent detection of the emission and atmospheric fallout of contaminants. Its capacity to concentrate heavy metals and other chemicals (phenols, pesticides, etc.) is currently being investigated. Some studies use lichens to qualify areas located near a source of pollution. The species are classed according to tolerance: the most sensitive organisms are present only in unpolluted environments.

LeBlanc and De Sloover (1970) mapped the Island of Montreal, as well as the sector affected by the foundries located around Sudbury, where atmospheric emissions are considerable. A second method consists in culturing lichens on a board of wood and observing the texture, colour and growth of the colony that develops. That colony is put to periodic analysis and the species are classed by differential degradation. This is a simple, practical and inexpensive technique. Land mosses can also concentrate certain heavy metals, chiefly mercury (Huckabee 1973). In fact, this author used a moss sensitivity index to qualify areas contaminated by heavy metals.

In Belgium a few species are used for long-term monitoring of nuclear power plants. These organisms prove to be excellent radionuclide integrators. Unfortunately, the colonies disappear when the radionuclide concentration increases.

Trees and other plants

Despite accessibility and rapid identification, analysis of the tree biomass is difficult. We still do not understand many of the mechanisms governing growth or gaseous interchange with the biosphere. Nor do we fully know the accumulation areas or the physiological responses to environmental stress.

For the use of this group as a BI, study of the growth of colonies is preferred to that of individuals. Kress and Skelly (1977) analysed the environmental impact of what they term a "supply" industry. Two aborescent species of pine and sycamore were chosen mainly for their economic interest. Analysis of species growth reveals an average 26% reduction, i.e., foliar reduction induced by the emission of ozone (O_3), NO_2 and SO_2 was observed at gaseous concentrations below the norms set by the US National Ambient Air Quality Standards. The sensitivity of these two species allows for the maintenance of a pollution bioindicator system that is viable in the long term. In general, fir trees exhibit less tolerance than deciduous species.

A few isolated studies examine other plants as potential biological indicators. The common horsetail (Equisetum arvense)* is well-suited for short-term analyses (Sankar et al. 1978). It has the advantages of being widely distributed, easily harvested and rapidly identified, as well as having a high tolerance and a high heavy-metal concentration factor. Accumulation occurs mainly at the roots.

Tobacco leaves are used in several US states to trace certain oxiding pollutants, including ozone (O_3), NO_3 and peroxyacetyl nitrate (PAN), all compounds of the photochemical complex (Heck 1971). The use of tobacco leaves is simplified by the continuous formation of new leaves during the growing season, the differential sensitivity of the leaves with age and the visual distinction of new lesions.

Special case: Tradescantia

The Tradescantia plant is represented by some 30 species growing on the US East Coast. Genetic cross-breeding of several subspecies has produced two hydrids,* Tradescantia 02 and Tradescantia 4430. These two hybrid

species are sensitive to atmospheric pollutants, which trigger various reactions in the plant: chromosomic alterations of the microspores, roots and stamens; somatic mutation of the petals and stamens; pollen abortion; and cellular sterility of the stamen bristles.

These reactions engender the emergence of physical changes over the short term, i.e., after 10 to 15 days of exposure to a contaminated environment. For example, the characteristic blue of the flowers gradually changes to pink with the intensity of radiation exposure. Visual observation of the phenotype may be accompanied by quantitative analysis involving a count of the stamen cells that have undergone mutation.

Tradescantia reacts to the presence of radionuclides ranging between 1 and 15 mGy and of chemicals, e.g., 1,2-dibromoethane and trimethyl phosphate (two gasoline additives), SO_2, NO_2 and vinyl chloride. But these doses are far too high for use in environmental monitoring (Schrairer et al. 1982). Research aimed at finding hybrids capable of reacting at lower doses is currently picking up pace.

2.2 Animal biological indicators

2.2.1 Aquatic animal BIs

Extensive research has been conducted on BIs in the aquatic environment. Virtually all taxonomic groups have produced interesting BIs, although macroinvertebrates are by far the most commonly used at present. Our attention here is focused on three groups of organisms, namely, zooplankton, macroinvertebrates and fish.

Zooplankton

We use the term zooplankton here to designate all animal organisms floating on or near the water surface. This encompasses Protozoa (Foraminifera,* Ciliata and amoeba,* etc.) and small crustaceans (Copepoda,* Cladocera, etc.), as well as fish, mollusk and other larvae. These organisms have a simple homeostatic* system that allows faster response to suboptimal living conditions than among higher organisms. It should be noted that our classification of bacteria in this group was a purely arbitrary decision.

The Escherichia coli count has long been used to ascertain water contamination by organic contaminants. Bacteria are less efficient in case of inorganic pollution; mutations providing for adjustment to stress prevent their being valid biological indicators. In 1978 Beckman Inc. (laboratory instruments) introduced the Microtox method, which uses luminescent bacteria to measure environmental stress in vitro. This technique is extremely sensitive, on the order of the ppb, and economical as well. It is used mainly to detect the presence of organic substances. Protozoa,* such as ciliates and foraminifers, which were neglected at one time, are beginning to be recognized as valid BIs (Antipa 1977). Evidently, their advantages (see Appendix B) balance out the disadvantages of using these unicellular animals.

In addition to protozoans, the zooplankton comprises small crustaceans floating on or near the water surface. These animals prove to be valid biological indicators. An in vitro method employing daphnids is commonly used to estimate inorganic contamination (AFNOR 1974). This technique is based on observation of the movements of the animals in the presence of toxic substances.

Macroinvertebrates

Mollusks, especially gastropods and bivalves, best meet the BI selection criteria listed in Table I. Their sedentarity, a particularly desirable characteristic, allows for study of the real ambient environment of these organisms. It should be noted that the drift of microorganisms was one of their major drawbacks, making them less acceptable as BIs. Several studies point out the considerable value of mollusks for environmental monitoring. But despite its many advantages, this group has a number of disadvantages as well (see Appendix B). No other group of organisms is put to more scrutiny than mollusks, although algae and a number of macrophytes have equal--if not more--potential as BIs.

Other groups of macroinvertebrates comprise a few species that can be used as BIs. Arthropoda* have some potential: amphipods and the larvae of Plecoptera* are indicators of water acidity; gammarids* are strong cadmium concentrators; the blue crab has a strong capacity to detect organic products (Appendix B).

Tubificida* are used especially in environments contaminated by organic pollution. Given their oxygen binding capacity, which stems from their high hemoglobin content, these organisms are more resistant to a drop in ambient oxygen (Aston 1973). In addition, they could ultimately be used in analyses of inorganic pollution (Saether 1979, Wilson and McGill 1977).

Tunicata* have proved very useful for evaluating disturbances in marine environments. Depending on the species chosen, they have been used to detect selenium, chromium, iron, zinc and cobalt (Appendix B). Other marine animal studies are in progress.

Polychaeta,* Ostracoda* and Echinodermata* (Word et al. 1977) are some secondary groups that have been investigated for their potential as indicators. But research in this area is far less advanced than for mollusks.

Fish

Fish are interesting BIs owing to their close economic, recreational and gastronomic links with humans. The chosen species will be mainly those encountered in sports fishing or consumed by humans.

The main two disadvantages of using fish as BIs are their mobility and the difficulty of collecting samples. These two problems are eliminated with the method proposed by the American Cairns, who has conducted in vitro research into the physiological responses of fish raised in an aquarium filled with industrial effluent water (Appendix B) (Cairns and Gruber

1980). However, the tremendous cost and several flaws in this method (e.g., variability of intraspecific behaviour and imprecise coefficient of dilution) make it difficult to put into practice.

2.2.2 Terrestrial animals as BIs

Little use has been made of terrestrial animals as biological indicators. This is attributable mainly to two factors. First, the low density of the populations prevents valid, representative sampling. Second, the capture of individuals from most species requires excessive labour.

Putting aside these drawbacks, it may be advantageous to analyse certain animal species, depending on environmental conditions. Appendix B4 mentions a few studies that explore the indicator potential of certain animals: earthworms apparently indicate soil contamination; amphibians and reptiles could be useful in areas where dense populations exist; birds have been used in the past to detect the intake of chemical substances (e.g., DDT) into the ecosystem. But given considerable mobility, they are not used on a routine basis. Mammals, although advantageous in certain respects, are often ruled out as BIs given that other organisms are more readily accessible.

CONCLUSION

In this study we have noted two classes of organisms used for this type of analysis: organisms that integrate environmental contaminants over the long term (e.g., mosses and lichens) and organisms that exhibit a short-term response to environmental stress, e.g., the Tradescantia plant.

Biological analyses provide an additional tool for estimating the effects of human manipulation of the environment. Appendix D indicates the present status of the use of BIs based on letters received from various Canadian and US organizations. The replies make up a monograph on the subject. We present here a few conclusions taken from these letters.

(1) Biological analyses based on the holistic or the reductionist approach are increasingly employed in environmental monitoring programs.

(2) Surprisingly, the present trend seems to favour the holistic approach over the reductionist approach.

(3) The results of biological analyses are often non-specific. These analyses are useful more in the long term as environmental stress monitors.

(4) Current biological analyses lack the sensitivity for short-term detection of disturbances induced by radioactivity.

(5) In cases where BIs are used, the selection criteria are often tied to economic and human health factors.

(6) Ideally, both chemical and biological methods should be used to evaluate environmental stress, as these two approaches are complementary.

According to this study, there are few biological indicators specific to radioactivity. But the nuclear industry can use indicators for their response to the chemical properties of radioactive effluents. Thus the use of biological indicators would appear to be valid for certain environmental monitoring programs. Organisms amenable to long-term integration of radioactive waste are already included in the programs of some AECB licence-holders. Rare are the organisms that exhibit short-term response to radioactivity. Research in this area might uncover species capable of rapid detection of radioactive waste.

RÉFÉRENCES

AFNOR, 1974. Détermination de l'inhibition de la mobilité de Daphnia magna straus (Crustacés, Cladocères). T 90-301, Association française de normalisation, avril, Paris.

ALABASTER, J.S., 1977. "Biological monitoring of inland fisheries." Applied Science, Londre, 226 p.

ANTIPA, G.A., 1977. "Use of commensal protozoa as biological indicators of water quality and pollution." Trans. Amer. Micros. Soc., 96(4): 482-489.

ASTON, R.J. 1973. "Tubificids and water quality: a review." Environmental pollution, 5(1): 1-10.

AUGIER, H., G. Gilles et G. Ramonda, 1977. Utilisation de la phanérogamme marine Posidonia oceanica Delile pour mesurer le degré de contamination mercurielle des eaux littorales méditerranéennes. C.R. Acad. Sc. Paris, t. 285, Série D. 1557-1560.

BEAULIEU, G., 1982. Des algues pour détecter la pollution des eaux. Réseau, 13(8): 14-17.

BECKMANN, 1978. "Microtox acute water toxity Monitor." Product Development Bulletin 6964.

BEDFORD, B.L., 1977. "Alterations in the growth and phenology of wetland plants as indicators of environmental change." Sensing of env. polluants 4th joint conf. Nouvelle Écosse, Nov. 6-11 (5): 170-174.

BENGTSSON, B.E., 1979, "Biological variables, especially skeletal deformities in fish, for monitoring marine pollution." Phil, Trans. R. Soc. Land. B. 286: 457-464.

BROCK, T.D., I. Yoder, 1971. "Thermal pollution of a small river by a large university: Bacteriological studies." Indianna academy of science. Proceedings, 80: 183-188.

BURNS, K.A. et J.L. Smith, 1981. "Biological monitoring of ambient water quality: the case for using bivalves as sentinel organisms for monitoring petroleum pollution in coastal waters." Estuarine, Coastal and Shelf science, 13: 433-443.

CAIRNS, J. Jr., et D. Gruber, 1980. "A comparison of methods and instrumentation of biological early warming systems." Water resources bulletin 16(2): 261-266.

CAIRNS, J., K.L. Dickson et G.F. Westlake, 1976. "Biological monitoring of water effluent quality." American society fortesting and materials (ASTM) STP607 04-6070000-16, 246p.

CAIRNS, J. Jr., G.R. Lanza, et B.C. Partker, 1972. "Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa." Proceedings of the Academy of Natural Sciences of Philadelphia, 124(5): 79-127.

CAMPBELL, W.F., et E.A. Rechel, 1979. "Tradescantia: A super-snooper of radioactivity from uranium mill wastes." Utah agricultural experiment station, UTAH Science, 40(4): 100-103.

COATES, K., D.V. Ellis, 1980. "Enchytraeid oligochaetes as marine pollution indicators." Marine pollution bulletin, 2(6): 171-174.

COOK, S.E., 1976. "Quest for an index of community structure sensitive to water pollution." Environmental pollution, 11(4): 269-288.

COWEN, J.P., V.F. Hodge, et T.R. Folsom, 1976 "In vivo accumulation of radioactive polonium by the giant kelp Macrocystis pyrifera." Marine biology, 37(3): 239-248.

DAJOZ, R. 1975. Précis d'écologie, Gauthier-villars, Bordas, Paris 546p.

DAPSON, R.W., et L. Kaplan, 1979. "Biological half-life and distribution of radiocésium in a contaminated population of greenfrogs Hyla cinerea." Oikos, 26: 39-42.

DICKS, B., 1973. "Some effects of Kuwait crude oil on the limpet, Patella vulgata." Environmental pollution, 5(3): 219-229.

DRUMOND R.A., G.F. Olson, et A.R. Batterman, 1979. "Cough response and uptake of mercury by brook trout, Salvelius fontinalis, exposed to mercuric compounds at different hydrogenion concentrations." Trans. amer. fish. soc.: 244-249.

EPA, 1982. "Biological monitoring." U.S. Environmental Protection Agency, no. EPA-1001.

FOULQUIER, L. et A. Grauby, 1974. Propositions pour un radioindicateur biologique international des milieux aquatiques, à partir d'un bilan expérimental, écologique et économique. Environmental surveillance around nuclear installations, Proceedings of a symposium Warsaw 5-9 Nov., AIEA, Vienne, 11: 67-89.

FOWLER, W., 1980. "The use of biological indicators as an index of stream health." Management sym. Spokane, Apr. 8-10: 69-80.

FRANCIS, G.R., 1976. "Summary observations on Canadian reptiles and amphibians." Canada's threatened species and habitats, p.133-135.

GILBERT, O.L., 1970, "A biological scale for the estimation of sulphur dioxide pollution." New Phytologist, 69(3): 629-634.

GORDEN, R.W., et C.B. Fliermans, 1978. "Survival and viability of Escherichia coli in a thermally altered reservoir." Water research, 12(5): 343-352.

GRAY, J.S. et R.J. Ventilla, 1973. "Growth rates of sediment living marine protozoans as a toxicity indicator for heavy metals." Ambio, 2(4): 118-122.

GROSSMAN, K., 1979. "The Spiderwort: Radiation monitor." Garden, 3(3): 22-25.

HARGREAVES, J.W., C.F. Mason et I.R. Pomfret, 1979. "A simplified biotic index for the assessment of biologically oxidyable pollution in flowing waters." Water pollution control, 78(1): 98-105.

HARVEY, R.S., 1970. "Biological indicator of environmental radioactivity." E.I. du Pont de Nermours and Co., Savannah River Lab., no. 71-4TG, 415p. (:136-139).

HAWKSWORTH D.L., 1974. "Lichens and Indicators of Environmental Change." Environment and Change, 2(6): 381-386.

HECK, W.W., 1971. "The use of plants on sensitive indicators of photochemical air pollution." International Symposium on Identification and Measurement of Environmental Pollutants, Ottawa, Canada, June 14-17.

HODGE, V.F., F.L. Hoffman, et T.R. Folsom, 1974. "Rapid Accumulation of Plutonium and Polonium on Giant Brown Algae." Health Physics, 27: 29-35.

HOFFMAN, I., 1971. "International Symposium on Identification and Measurement of Environment Pollutants." Ottawa, Canada, June 14-18. 451p.

HOOK, V.R.I., 1974. "Cadmium, lead, and zinc distributions between earth worms and soils: Potentials for biological accumulation.1 Bull. Env. Contam. and toxical, 12(4): 509-511.

HUCKABEE, J.W., 1973. "Mosses: Sensitive Indicators of Airborne Mercury Pollution." Atmospheric Environment, 7(7): 749-754.

ICHIKAWA, R., 1961. "On the Concentration Factors of some Important Radionuclides in the Marine Food Organisms." Bulletin of the Japanese Society of Scientific Fisheries, 27(1): 66-74.

JAMES, A., L. Evison, 1979. "Biological indicators of water quality." John Wiley and Sons, 600p.

JOUBERT, G., 1980. "A bioassay application for quantitive toxicity measurement, using the green algae Selenastrum capricornutum." Water Research, 14: 1759-1763.

KAESLER, R.L., J. Cairns Jr., et J.S. Crossman, 1974. "Redundancy in Data from Stream Surveys." Water Research 8(9): 637-642.

KALIN, M. et H.D. Sharma, 1981. "Lead total and lead-210 in 20 year old uranium mill tailings." Proceedings: Conference on Radiation Hazards in Mining. Golden. Colorado 4p. Oct.

KINGSBURY, R.W.S.M. et C.P. Rees, 1978. "Rapid Biological Methods for Continuous Water Quality Monitoring." Effluent and Water Treatment Journal, 18(7): 319-331.

KIRCHMANN, R., J. Lambinon, E. Bonnijns-van Gelder et J. Colard, 1974. Utilisation de bioindicateurs à des fins de surveillance des sites nucléaires. AIEA-SM-/80-55: 105-118.

KRESS, L.W., et J.M. Skelly, 1977. "The interaction of O_3, SO_2 and NO_2 and its Effect on the Growth of two Forest Tree Species." Présenté à "Cottrell Centennial Sym. on Air Pollution and its Impact on Agriculture", Californie, Jan. 13-14: 128.

KRIEGER, R.I., S.J. Gee, L.O. Lim, J.H. Ross et A. Wilson, 1979. "Disposition of Toxic Substances in Mussels (Mytilus Californianus): Preliminary Metabolic and Histologic Studies." American Chemical Society: 259-277.

KRISHNAMOORTTI, K.P., et M.K. Abdulappa et A. Gadkari, 1978. "Biological indicators of pollution." Proc. Indian Natl. Sci. Acad. Partie B. 44(2): 98-119.

KURABAYASHI, M., S. Fukuda et Y. Kurokawa, 1979. "Concentration Factors of Marine Organisms used for the Environmental Dose Assessment." Power Reactor and Nuclear Fuel Development Corp., Tokyo: 336-345.

LAMBINON, J., J.-P. Descy, A. Empain, R. Kirchmann, et E. Bonnijns-Van Gelder, 1976. La surveillance écologique des sites d'implantation des centrales nucléaires: Effets des rejets d'effluents pour l'écosystème mosan: Acquis et Perspectives. Annales de l'Association Belge de Radioprotection, 2(3): 201-215.

LEBLANC, F. et J. De Sloover, 1970. "Relation between industrialization and the distribution and growth of epiphytic lichens and mosses in Montréal." Canadian Journal of Botany, 48: 1485-1496.

LEBLANC, F., D.N. Rao et G. Comeau 1971. "The epiphytic vegetation of Populus balsamifera and its significance as an air pollution indicator in Sudbury, Ontario." Can. J. Bot., 50: 519-528.

LEEUWAUGH, P. 1978. "Toxicity Rests with Daphnids: its Application in the Management of Water Quality." Hydrobiologia, 59(2): 145-148.

LEVY, C.K., Youngstrom, K.A. et C.J. Maletskes, 1981. "Radioecology on a Nuclear Power Station Site using Recapturable Wild Birds and Whole Body Gamma Spectroscopic Analysis." International Symposium on Migration in the Terrestrial Environment of Long-lived Radioculides from the Nuclear Fuel Cycle, Knoxville, Tennesse, USA 27-31 July 81. IAEA-SM-257-260.

MAJORI, L., G. Nedoclan, G.B. Modonutti et F. Daris, 1970. "Methodological Researches on the Phenomenon of Metal Accumulation in the Mytilus galloprovincialis and on the Possibility of using Biological Indicators as Tests Organisms of Marine Metal Pollution." Revue int. d'Oceanographie Médicale, XLIX: 81-87.

MARTOJA, M., Vu Tan Tu et B. Elkaim, 1980. Bioaccumulation du Cuivre chez Littorina litterea (L.) (gastéropode prosobranche): Signification physiologique et écologique. J. exp. mar. Biol. Ecol., 43: 251-270.

McMAHAN, E.A., 1972. "Relative Abondance of Three Marsh-Floor Organisms in a Sewage-Affected Marsh and in a Sewage Free-Marsh." The Journal of the Mitchel Society: 61-65.

McMAHON, J.W. et A.E. Docherty, 1978. "Phytoplancton and cooling Systems: Temperature Effects using Different Intake and Discharge depths." Water research: 925-929.

MORSE, E.V., & M.A. Duncan, 1976. "Salmonella as Monitors of Fecal Pollution in the Aquatic Environment." J. Environmental Science and Engineering, 11(10-11): 591-601.

MURPHY, P.M., 1978. "The Temporal Variability in Biotic Indices." Environmental Pollution, 17(3): 227-236.

NAKAHANA, M., T. Koyanagi, Veda T., Shimizer C., 1979. "Peculiar Accumulation of Cobalt-60 by the Bronchial Heart of Octopus." Bulletin of the Japanese Society of Scientific Fisheries. 45(4): 539.

NAKAHANA, M., T. Koyamagi et M. Saiki, 1975. "Concentration of radioactive cobalt by seaweeds in the food chain." Impacts of Nuclear releases in the Aquatic Environmental, AIEA, Vienne, p.301-313.

NALEPA T.F., 1979. "Freshwater Macroinvertebrates." Journal Water Pollution Control, 51(6): 1694-1708.

PAPADOPOULOU, C., et G.D. Kanias, 1977. "Tunicate Species as Marine Pollution Indicators." Marine Pollution Bulletin, 8(10):229-231.

PATEL, B. et A.K. Ganguly, 1973. "Occurrence of ^{75}Se and ^{113}Sm in Oysters." Health Physics, 24: 559-562.

PERSOONE, G. et N. Pawn, 1979. "Systems of Biological Indicators for Water Quality Assessment." In Biological Aspects of Freshwater Pollution. O. Ravera (ed), Pergamon, p.39-75.

PESSON, P., 1976. La Pollution des eaux continentales: Incidence sur les biocénoses aquatiques. Gauthier-Villars, Bordas, 285p.

PHILLIPS, D.J.H., 1977. "The Use of Biological Indicator Organisms to Monitor Trace Metal Pollution in Marine and Estuarine Environments - A review." Environmental Pollution, 13(4): 281-317.

RAVERA, O., 1978. Evaluation of effects of radioactive contamination of the marine biota. Revue int. d'Océanographie Médicale, XLIX(3): 147-167.

RESH, V.H., J.D., Unzickep, 1975. "Water Quality Monitoring and Aquatic Organisms: the Importance of Species Identification." Water Pollution Control, 47(1): 9-19.

ROGERS, H.H., H.E. Jeffries et A.M. Witherspoon, 1979. "Measuring Air Pollutant Uptake by Plants: nitrogen dioxide." Journal of Environmental Quality, 8(4): 551-557.

RYAN, P.M., et H.H. Harvey, 1977. "Growth of Rock Bass, Amploplites rupestris in Relation to the Morphoedaphic Index as an Indicator of an Environmental Stress." J. Fish Res. Board Can., 34: 2079-2088.

SAETHER, O.A., 1979. "Chironomid Communities as Water Quality Indicators." Holartic Ecology, 2(2): 65-74.

SANKAR N., R. White and W.J. White, 1978. "Equisetum arvense: An Aquatic Vascular Plant as a Biological Monitor for Heavy Metal Pollution." Chemosphere, 8(3): 125-128.

SAUNDERS, J.W., 1969. "Mass Mortalities and Behaviour of Brook Trout and Juvenile Atlantic Salmon in a Stream Polluted by Agricultural Pesticides." J. Fish Res. Bd. Canada, 26(3): 695-699.

SAWICKA-KAPUSTA, K., 1979. "Roe Deer Antlers as Bioindicators of Environmental Pollution in Southern Poland." Environmental Pollution, 19(4): 283-293.

SCHAIRER, L.A., R.C. Sautkulis et N.R. Tempel 1982. "Monitoring Ambient Air for Mutagenicity using the Higher Plant Tradescantia." Genotoxic Effects of Airborne Agents, 123-139.

SCHAIRER, L.A., J. Van't Hof, C.G. Hayes, R.M. Burton et F.J. de Serres, 1979. "Measurement of Biological Activity of Ambient Air Mixtures used a Mobile Laboratory for in situ Exposures: Preliminary Results from the Tradescantia Plant Test System." In Application of short-term Bioassays in the fractionation of complex environmental mixtures. Waters, M.D., S. Nesnow, J.L. Hwisingh, S.S. Sanhu et L. Claxon (eds), Plenum, New York. p. 421-444.

SCHRECK, C.B. et H.W. Lory, 1978. "Stress Response of Coho Salmon (Oncorhynchus kisutch) Elicited by Cadmium and Copper and Potential Use of Cartisol as an Indicator of Stress." J. Fish Res. Board Can., 35(8): 1124-1129.

SIMMONS, G.M. Jr. et J.R. Reed Jr., 1973. "Mussels as Indicators of Biological Recovery Zone." Journal WPCF, 45(12): 2480-2492.

SPARROW, A.H. et L.A. Schairer, 1974. "The Effects of Chemical Mutagens (EMS, DBE) and Specific Air Pollutants (O_3, SO_2, NO_2, N_2O) on Somatic Mutation Rates in Tradescantia." Conférence présentée à Moscou lors du symposium sur "The Potential Genetic Effects of Environmental Pollutants on Man" février, 18-21.

TIBBS, J.F., 1974. "Testacea (Protozoa: Sarcodina) as Indicators of Water Quality in Western Montana." Montana Water Resources Center, Report No. 49, 7p.

VARSHENEY, C.K. et J.K. Garg 1979. "Plant responses to Sulfur Dioxide Pollution." Critical Reviews in Environmental Control, 9(1): 27-49.

WIEDERHOLD, T., 1980. "Use of Benthos in Lake Monitoring." Journal WPCF, 52(3): 550-547.

WIELGOLASKI F.E. 1975. "Biological Indicators of Pollution." Urban Ecology, 1: 63-79.

WILSON, R.S. et J.D. McGill, 1977. "A new method of monitoring water quality in a stream receiving sewage effluent, using chironomid pupal exuviae." Water Research, 11(11): 959-962.

WORD, J.Q., B.L. Myers et A.J. Mearns, 1977. "Animals that are indicators of marine pollution." Coastal Water Research Project, 253p.

ZACH, R., et K.R. Haysh, 1982. "Breeding Biology of Tree Swallows and House Wrens in a Gradient of Gamma Radiation." Ecology, 63(6): 1720-1728.

ZAUKE, G.P., 1979. "Cadmium in Gammaridae (Amphipoda: Crustacea) of the Rivers Werra and Weser; 1. Evaluation of the Sources of Variance." Chemosphere, 8(10): 769-775.

APPENDIX A

ADVANTAGES AND DISADVANTAGES OF PLANTS AS BIs

1. Advantages and disadvantages of selected aquatic plants as BIs - Phytoplankton

ADVANTAGES	DISADVANTAGES
. Possibility of obtaining a universal index for assessing the quality of aquatic environments (Wielgolaski 1975).	. Labourious study, i.e., sampling, identification and counting, analysis and interpretation.
. Several species are sensitive to thermal or organic pollution (McMahan 1972, MaMahon and Docherty 1978).	. Taxonomic key may not be available.
. Particularly useful for toxicity studies: easily cultured, short-term results. Selenastrum capricornutum has a simple cellular morphology and is well-suited for analysing the enrichment of aquatic environments (Joubert 1980).	. The representativity of the indicator species is often questioned. . Some critics point up the non-specificity of these analyses.
. Several microalgae react to the presence of toxic substances: Oscillatoria vaucher, Skeletoma costatum, chlorella ovalis, Anabeana floraqnal, Microcystis acruginosa (EPA 1971).	. The drifting of this group comprises certain disadvantages.

2. Advantages and disadvantages of selected aquatic plants as BIs - Macroalgae

ADVANTAGES	DISADVANTAGES
. Large biomass, easy harvesting and rapid identification; high concentration factor; well-suited for bioaccumulation studies. . Brown algae are widely used: Cladophora sp. is a good concentrator of Ru, Sr, Ge, Zr/Nb, Pu, I and several heavy metals (Kurabayshi et al. 1979). Macrocystis pyrifera (laminar) can accumulate Pu and Po and has a rapid growth rate providing for short-term results (Cowen et al. 1976). Fucus senatus has been used in several studies to trace heavy metals (Hodge et al. 1974). Filamentous green algae accumulate Mn-54, Co-60, Cs-14 and Cs-137 (Nakahana et al. 1975).	. This plant group grows in a habitat restricted by depth and luminosity and is confined to the marine coast.

3. Advantages and disadvantages of selected aquatic plants as BIs - Riparian plants

ADVANTAGES	DISADVANTAGES
. Aquatic mosses are readily accessible and easy to harvest.	. Restricted to long-term analysis.
. A high concentration factor makes this group one of the best BIs.	. Identification requires special expertise.
. The possibility of building an index to map the various zones simplifies spatial analysis.	. Mosses grow only in specific areas.
. Slow growth provides for better adaptation to the environment.	. They are extremely sensitive to pollution and disappear under highly polluted conditions.
. Cinclidotus danubicus and Platyhypinidium sp. have been used for years in Belgium to trace Mn-34, Co-60, Cs-134, Cs-137, Co-59 and heavy metals (Kirchmann et al. 1974)	
. Rhynchostegum riparioides is widely distributed in the rivers of the northern hemisphere and tolerates many toxic substances.	
. Littoral plants inhabit the transfer zone between water and land. They are generally readily accessible and easy to harvest and identify.	. Relatively short sampling period.
. Typha latifolia, Carex lacustris, Bideus and Cernua are used to assess the effects of thermal stress on vegetation (Bedford 1977)	. The plants studied to date have an average concentration factor and a very limited habitat.

3. Advantages and disadvantages of selected aquatic plants as BIs - Riparian plants (continued)

ADVANTAGES	DISADVANTAGES
. Hordeum jubatum, Pucinella distans and Deschampsia cispitosa accumulate Ra-226 and Pb-210. They have been used as bioindicators in old abandoned mines (Kalin and Sharma 1981).	
. Myriophyllium sp. and Potamogeton crisplus can concentrate certain radionuclides (Mn-54, Co-60 and Cs-137).	

4. Advantages and disadvantages of selected terrestrial plants as BIs

ADVANTAGES	DISADVANTAGES
. Lichens grow in large abundance.	. A very slow growth rate allows for long-term analysis only.
. A very high concentration factor makes them one of the best bioaccumulators.	. The species is sensitive to pollution and disappears when environmental contamination reaches a certain level.
. Having a simple physical structure, lichens are excellent integrators of the environment. Tolerance indices based on the degree of pollution exist and can be used to map the affected areas (Leblanc et al. 1970-71, Gilbert 1970, Hawksworth 1974).	. Identification requires special expertise.
. Enernia sp. and Hypogymnia sp. are excellent accumulators of heavy metals and radionuclides.	
. Parmelia physodes is used to detect excess SO_2, hydrofluoric acid and hydrochloric acid (Rogers et al. 1979).	
. A few studies have focused on trees in view of their large biomass and easy harvesting and identification.	. The use of shrub species as environmental indicators calls for major long-term studies. Little is known about the mechanics of response to environmental stress.
. Tradescantia exhibits rapid, visible physical response to environmental stress (after 10-15 days of exposure). This flowering plant is easy to handle, stores well in a growing chamber and responds to several pollutants (Schairer et al. 1982, Schairer et al. 1979, Grossman 1979, Campbell and Rechel 1979, Sparrow and Schairer 1974).	. Counting stamen* cells can be labourious work. . The first mutations occur only at fairly high concentrations. There is some lack of efficiency, but this can be improved with new, more sensitive hybrids.

APPENDIX B

ADVANTAGES AND DISADVANTAGES OF ANIMALS AS BIs

1. Advantages and disadvantages of selected aquatic animals as BIs - Zooplankton

ADVANTAGES	DISADVANTAGES
Bacteria	
. Good organic pollution indicator (Morse and Duncan 1976) (a) by conventional counting method (b) by Microtox method using luminescent bacteria (Beckmann 1978).	. Drifting organisms (a) rapid recovery from environmental stress (b) specialized equipment: sterilizer, Petri dish, etc.
. Rapid response to environmental change.	. Delay in obtaining results due to culture of bacteria.
. Easy sampling.	. Dead and live cells hard to differentiate.
. Well-developed methodology.	. No precise way of counting.
. Good thermal pollution indicator (Brock and Yoder 1971).	. Not used for inorganic pollution (Gordan and Fliermans 1978).
. Resistant to radioactivity (especially spores) (Ravera 1978).	. Mutations occur in response to environmental stress and make the bacteria inefficient as BIs for certain toxic substances (Helawell *in* Alabaster 1977).
Protozoans	
. Rapid response to environmental change (Cairns *et al*. 1972).	. Taxonomic expertise required.
. Easy sampling (Tibbs 1974).	. Identification tools unavailable.
. Well-researched saprobic valence (Antipa 1977).	. Studies are necessarily quantitative.

1. Advantages and disadvantages of selected aquatic animals as BIs - Zooplankton (continued)

ADVANTAGES	DISADVANTAGES
. May be resistant to physical factors of water (e.g., temperature) but sensitive to chemical factors (e.g., phosphates, sulfates, nitrates and silicates) (Gray and Ventilla 1973). Ex.: Foraminifera (Barlett in Hoffman 1971) and Ciliata.	. Drifting organisms.
Small crustaceans	
. Rapid response to environmental change.	. More or less drifting organisms.
. Easy sampling.	. Average resistance to pollutants.
. Behavioural response to stress, e.g., motility, can be analysed (AFNOR 1974).	. Most species (e.g., daphnids) are better suited for toxicity studies than as biological indicators (Leeuwangh 1978).

2. Advantages and disadvantages of selected aquatic animals as BIs - Macroinvertebrates

ADVANTAGES	DISADVANTAGES
General	. A few drifting species.
. Concentration factors 2 to 3 times higher than for fish.	. Inadequate taxonomic key for a few species.
. Many sedentary species.	. Qualitative sampling abandoned.
. Good taxonomic key for many species.	. Small-sized individuals.
. Allow for qualitative studies.	
. Easy sampling.	
. Simple sampling equipment.	
. Resistant to radioactivity (more than vertebrates) (Ravera 1978).	
Mollusks	
. Good indicators of heavy metals and other chemical substances (e.g., phenol, water pH, cobalt, zinc) (Burns and Smith 1981, Dicks 1973, Majori et al. 1970).	. Hemocyanin* mollusks are not resistant to copper-based substances and cannot be used as a BI (molluscoids) (Martoja et al. 1980) in case of copper contamination.
. Last taxonomic group to recolonize a stressed environment (Simmons and Reed 1973).	. Dead and live mollusks sometimes hard to differentiate.
. Weak metabolic transformation of foreign chemical substances and thus a long biological half-life (Krieger et al. 1979).	. Certain species have little concentrating capacity.
. Integration of pollutants by three pathways:	. May be present in low density.
(a) absorption through water (b) absorption through food (c) adsorption of inorganic filtrated particles.	

2. Advantages and disadvantages of selected aquatic animals as BIs - Macroinvertebrates (continued)

ADVANTAGES	DISADVANTAGES
. Transplantation possible.	
. Bivalves are particularly useful for dosing Mn-54; they can accumulate radioactive substances on the order of 10^3 to 10^6 (Ichikawa 1961).	
. Oysters are particularly good accumulators of radionuclides (Zn-65, Mn-54, Co-60, Fe-54, Cr-51, Cs-137, Ce-141-144, Ru-106, Zr/Nb-95, Ag-113m) (Patel and Ganguly 1973).	
. The branchial heart of the octopus (cephalopod)* accumulates Co-60 and Mn-54 at high concentrations. But plutonium is more strongly concentrated in the other families of mollusks (Makahara et al. 1979).	
Other macroinvertebrates	
. Tubificids, employed mostly for organic pollution, are increasingly used to indicate inorganic pollution (Aston 1973).	. With the exception of tubificids, population densities are too low to consider these organisms as truly valid indicators.
. Owing to their large capacity for concentrating selenium, chromium, iron, zinc and cobalt, marine tunicates have proven good BIs (Papadadopoulou and Kanias 1977).	
. Gammarids are useful as concentrators of cadmium (Zauke 1979).	
. Amphipods and plecoptera larvae are valid indicators of water acidity (Wielgolaski 1975, Coates and Ellis 1980).	

3. Advantages and disadvantages of selected aquatic animals as BIs - Fish

ADVANTAGES	DISADVANTAGES
. Immediate effects of pollutant on fish physiology (Scheck et al. 1978).	. Stress responses not fully understood.
. Well-developed methodology.	. Mobility.
. Good taxonomic key.	. Evasive behaviour in presence of pollutant (Saunders 1969).
. High concentrator factor* for radiocesium.	. Sampling requires manpower.
. Large-sized individuals.	. Less sensitive to certain pollutants (e.g., Mn-54, Co-60) than are invertebrates.
. Sensitive to certain pollutants.	. Use of fish muscle to indicate concentration of pollutant in the ambient environment is not recommended (except for mercury) since no significant correlation has been uncovered (Drummond et al. 1979).
. High trophic level.	. High cost of apparatus for in vivo and in vitro study and monitoring.
. Clear detection of physiological impact: cardiac and respiratory rates (Ryan and Harvey 1977)	. Dilution of the effluent in the watercourse is not always considered upon in vitro testing.
. Clear detection of anatomical effects, e.g., skeletal deformation, tumours, lesions and damaged gills (Bengtsson 1979).	

4. Advantages and disadvantages of selected terrestrial animals as BIs

ADVANTAGES	DISADVANTAGES
. Invertebrates	
. Ex.: earthworms concentrate cadmium and zinc (Hook 1974).	
Amphibians	
. Ex.: frogs may concentrate radiocesium (Dapson and Kaplan 1979).	. Low population density. . Sampling difficult.
Reptiles	
. Francis (1976) observed that reptiles may accumulate pesticides.	. Low population density. . Sampling difficult.
Birds	
. Some wildfowl species (duck and partridge) have been used as BIs owing to their role in the human food chain (Harvey 1970).	. Low population density. . Sampling difficult.
. They have also been used to determine gamma fields (Zach and Hayoh 1982) and detect the accumulation of Cs-137 (Levy et al. 1981).	
Mammals	
. Mammals concentrate iodine-131 in the thyroid.	. Low population density. . Sampling difficult.
. Immediate physiological response.	
. The horns of certain ruminants are used as pollution indicators (Sawicks-Kapusta 1979).	

APPENDIX C
Glossary

AMOEBA (Amoibê = change) - Unicellular animal of the phylum of protozoans living in salt or fresh water and humid land areas.

AMPHIPODA - Order of small crustaceans (1 cm) having a laterally compressed body, including freshwater forms (gammarids) and marine forms (sand hopper).

ARTHROPODA (arthron = joint, podos = foot) - Phylum of invertebrate animals characterized by a chitinous shell, a segmented body and jointed limbs allowing for mobility.

BIVALVE - Name given to certain mollusks having a shell comprised of two valves.

BRYOPHYTA - Division of plants comprising the mosses and the spaghnums.

CEPHALOPODA (kephalê = head, podos = foot) - Marine mollusk having a head surrounded by tentacles with prehensile suckers.

CLADOCERA - Sub-order of crustaceans represented by the water fleas (daphnids).

CONCENTRATION FACTOR - A quantitative method of assessing the potential of living organisms to accumulate certain substances. The factor is defined as the ratio of the concentration of a substance in the organism to the concentration of the same substance in the ambient environment.

COPEPODA - Subclass of crustaceans comprising microscopic forms which make up part of the zooplankton.

CUTICLE - In botany, the cutin-containing outer surface of young stems and leaves. In zoology, the chitin-containing outer integument of articulate animals (insects, crustaceans).

DECAPODA - Order of higher crustaceans having five pairs of locomotive appendages terminating in a pincer or a claw; includes crab, shrimp, lobster, crayfish and hermit crab.

ECHINODERMATA (ekinos = hedgehog, sea urchin, derma = skin) - Phylum of invertebrates including type 5 radially symmetical marine forms; includes the sea urchin and the starfish.

EQUISETUM - Genus of plants growing in moist areas and having hollow stems, sheathed leaves and terminal spore cones. One widespread species is the common horsetail (E. arvense).

FORAMINIFERA - Order of marine protozoans comprised of individuals enclosed in a calcareous shell having minute openings.

GAMMARID - Small amphipod crustacean (1 cm) commonly found in aerated freshwater.

GASTROPODA (gastêr = abdomen, podos = foot) - Class of mollusks that creep on one flattened, muscular foot, often have a spirally coiled shell and live on land (snail, slug) or in freshwater (lymnaea) or the sea (periwinkle, whelk, etc.).

HEMOCYANIN - Copper-containing protein respiratory pigment found in solution in the blood plasma of most mollusks and crustaceans.

HEPATICAE - Class of Bryophyta having the same growth pattern as the mosses but more varied forms.

HOMEOSTATIC - Describes a system of fairly complex individuals which, left to themselves, are capable of maintaining a stable internal environment.

HYBRID - Describes an animal or plant resulting from cross-breeding between varieties or subspecies.

OSTRACODA - Subclass of pelagic or benthic crustaceans having a bivalve shell.

PHANEROGAMIA (phaneros = visible, gamos = union) - Division of the plant kingdom comprising the plants that reproduce by flowers or seeds.

PLECOPTERA - Order of mandibulate insects featuring heterometabolic metamorphosis. The larvae frequent rapid-moving rock-bottomed rivers and streams.

POLYCHAETA (polos = many, cahite = long, flowing hair) - Class of marine Annelida having numerous lateral bristles (e.g., nereids).

PROTOZOA (protos = first, zoon = animal) - Phylum of animals represented by unicellular microscopic organisms having varied means of locomotion.

STAMEN - Male sex organ of flowering plants consisting of a slender part (filament) and a ventricose part (anther) that holds the pollen.

STOMA - Microscopic opening (ostiole) in the epidermis of plant organs through which gaseous interchange with the atmosphere occurs.

TAXONOMY - Classification of biological organisms.

TUBIFICIDAE - Family of oligochaeta, small red worms that breathe by burying their head in the mud and agitating the opposite extremity in the water.

TUNICATA - Subphylum of protochorda comprising sessile animals having their body encased in a tunic (capsule).

UBIQUIST - Describes a species distributed through several different environments.

APPENDIX D

Letters from various organizations describing their use of BI methods

Province of
British Columbia

Ministry of
Environment

Assessment and
Planning Division
Aquatic Studies Branch
Parliament Buildings
Victoria
British Columbia
V8V 1X4

File: 64.0228

June 29, 1982

Carmel Létourneau,
Research and Development Division,
Atomic Energy Control Board,
P.O. Box 1046,
Ottawa, Canada.
K1P 5F9

Dear Mille Létourneau:

Thank you for your letter of June 16, 1982 .

In response to your request regarding our use of biological indicators for monitoring environmental stress, the Ministry of Environment presently has no standardized tests other than those designed to measure acute toxicity.

Some experimental work has been done at the University of Victoria measuring the metallothionein levels in the livers of fish. Metallothionein levels have been shown to increase when fish are exposed to sublethal concentrations of trace metals. This process is thought to protect key biochemical processes and thus, serve as an adaptive mechanism. This response, however, is specific for certain trace metals. References to this work are difficult since they are presently in press (McCarter et al. 1982. Comparative Biochem. Physiol. and Roch et al. 1982. Can. J. Fish. Aquatic Science.)

...2

Another test, the "corticosteroid" stress response bioassay has been suggested for measuring the response of fish to mixtures of toxicants. This test has been described by Donaldson, E.M. and H.M. Dye. 1975. Corticosteroid Concentrations in Sockeye Salmon Exposed to Low Concentrations of Copper, Jour. Fish. Res. Bd., Vol. 32 (4), Ottawa.

In most tests involving biological indicators, importance is placed on the use of a sensitive species, indigenous to the area in question. In B.C., salmonid species such as rainbow trout are frequently used due to their availability from hatcheries.

Both chemical and biological indicators of stress probably have their applications but neither type of text has shown to be superior.

I suggest you contact the following:

Dr. John Cairns, Jr.,
Centre for Environmental Studies
Virginia Polytechnic Institute and State University,
Blacksburg, Va. 24061

who is eminent in this field and familiar with work being done by others.

Yours truly,

R. J. Buchanan, Ph.D.,
Director,
Aquatic Studies Branch.

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.
Upton, Long Island, New York 11973
(516) 282
FTS 666 3332
Office of the Director

8 July 1982

Ms. Carmel Létourneau
Research and Development Division
Atomic Energy Control Board
P. O. Box 1046
Ottawa, Canada K1P 5S9

Dear Ms. Létourneau:

With respect to your recent letter on "biological indicators" for monitoring environmental stress, I am enclosing some reprints furnished by Mr. Lloyd Schairer of our Biology Department. Also enclosed are some comments on the overall usefulness, and the difficulties with such indicators, if they are utilized under other than the most carefully controlled conditions.

With respect to your specific question, I believe that Tradescantia is the only biological indicator to date to have been used operationally to monitor radiation and other kinds of environmental pollution. I do not know of any other system that has been used, or is contemplated for use in this regard. With respect to your second question, I do not know of a proposed system that would employ biochemical changes as an indicator. I believe that in general it takes a much larger dose to cause detectable biochemical changes, and that therefore this kind of monitor would not be nearly as sensitive as those which monitor mutational events.

Also, I do not know of true biological indicators presently in use in industry, or contemplated. At least with radiation, the reason is that we can measure radiation dose quite accurately even with very small exposures. Also, we cannot "extrapolate" any better to man with results from the biological indicators, than we can from the dose. Biological indicators have their main usefulness under those conditions in which there is very little knowledge about either the type or quantity of pollutants in the environment, or for those situations in which we may know the amount of a pollutant but have no "risk coefficient".

I hope the above will be of some use to you. With best wishes, I am

Sincerely yours,

V. P. Bond

V. P. Bond, M.D.
Associate Director

jal

Enclosures

0 667

MANITOBA
Environmental Management Division
Box 7, Building 2
139 Tuxedo Avenue
Winnipeg, Canada
R3N 0H6

Fo	40-0-6
Ref	C LETOURNEAU

July 9th, 1982

Carmel Létourneau,
Research & Development Division,
Atomic Energy Control Board,
P.O. Box 1046,
OTTAWA, Canada
K1P 5S9

Dear Ms. Létourneau:

This is in response to your enquiry of June 16, 1982 regarding use of biological indicators.

The Environmental Management Services Branch has a Terrestrial Standards and Studies Section which is involved in this field to a considerable degree using bioindicators in monitoring the distribution and effects of various pollutants, and preparing and evaluating "receptor standards" - those based on the response of indicators to a particular pollutant level.

Our Section deals with both vegetation/soils, wildlife and other animals. To answer your specific questions:

1. Indicators used in vegetation studies include changes in species composition, abundance and performance of a community, in addition to the content of pollutants in the plants and soils. Similarly, animal studies utilise physiological parameters, performance, abundance, and tissue contents of the species in question.

2. The plant species are selected based on availability, abundance, economic importance, and sensitivity. Examples are mosses and lichens used to trap heavy metals, or conifers damaged by SO_2 emissions.

   Animal studies use small mammals because of their abundance, wide distribution, and limited home ranges, game animals on account of their availability, economic importance, and relation to livestock, carnivores because of their top position in the food chains.

CO 839

. . ./2

3. Both chemical and biological methods are needed, to complement each other.

In conclusion, I wish you luck in your research, and want to ask for a copy of your report, when completed. Please include me on the distribution list.

Yours very truly,

Emil Kucera, Ph.D.,
Wildlife/Environment Research Biologist

EK/ja

Ontario Hydro

700 University Avenue Toronto Ontario M5G 1X6

Location: A7-A11
(416) 592-4368

July 5, 1982

Mr. C. Letourneau
Research and Development Division
The Atomic Energy Control Board
PO Box 1046
Ottawa, Ontario
K1P 5S9

Dear Sir:

In your letter of June 16, 1982, to Ontario Hydro, you request information on "biological indicators for monitoring environmental stress." It is assumed that you are considering measurement of cell damage or chromosome abberation which might result from exposure to some environmental pollutant, rather than measuring some behavioural change.

Ontario Hydro do not, and have no plans to perform such measurements because the radiological dose to which organisms may be exposed as a result of nuclear power plant operation is only a few millirads or less. This exposure is within the variation of natural background radiation and several orders of magnitude less than the level at which some biological change could be detected.

If your interest is in the impact of chemical rather than radiological emissions, Ontario Hydro has operated indicator vegetation plots in the vicinity of the coal burning Nanticoke Generating Station. These projects were terminated in 1978 as no SO_2 damage was ever observed. Biological indicator studies around Ontario Hydro generating facilities are currently performed by the Air Resources Branch of the Ontario Ministry of the Environment (S.N. Linzon, Phytotoxicology Section).

00 485

Mr. C. Letourneau Julu 5, 1982

If you require further information, please call, but it may be more useful to contact the Ontario Ministry Group.

A. Guest
Environmental Protection Section
Radioactivity Management and
Environmental Protection Department

AG:slb/A13

cc: B.C.J. Neil - Pickering CSS

H.P.-D.?

C. LÉTOURNEAU

Le 9 juillet 1982

Mademoiselle Carmel Létourneau
Direction de la recherche et
du développement
Commission de contrôle de
l'énergie atomique
C.P. 1046
Ottawa, Ontario
K1P 5S9

Mademoiselle,

En réponse à votre demande du 16 juin 1982, il me fait plaisir de vous confirmer qu'Hydro-Québec réalise un programme de surveillance écologique dans le secteur des centrales électronucléaires de Gentilly. Ce programme fut conçu principalement dans le but d'évaluer les modifications réelles engendrées par les installations nucléaires soit 1° par l'émission ou le rejet de substances radioactives ou 2° par les rejets thermiques.

Vous trouverez ci-joint un résumé du programme de surveillance radiologique de l'environnement dans lequel les principales composantes du milieu qui font l'objet des mesures sont identifiées. Ces composantes sont choisies dans le but de caractériser l'ensemble des voies de transfert des matières radioactives vers l'homme. A ce titre, certaines peuvent être considérées comme des indicateurs biologiques (Herbes, animaux, plantes aquatiques, poissons et mollusques bivalves), bien qu'ici le critère de choix soit plutôt la chaîne alimentaire que la capacité particulière d'une espèce à concentrer les substances radioactives.

Le programme de surveillance thermique porte sur le benthos, les bactéries saprophytiques hétérotrophes des eaux de surface, les macrophytes, les principaux paramètres physico-chimiques de l'eau et sur diverses espèces de poissons: Perca flavescens, Esox lucius, Catostomus commersoni et Ictalurus nebulosus. Bien que certaines espèces fassent l'objet d'une surveillance particulière, l'objectif principal de ce programme vise plutôt à suivre et à comprendre l'évolution des biocénoses car, à notre connaissance, le comportement des communautés est plus sensibles et, par conséquent, un meilleur indicateur des modifications du biotope.

.../2

0 930

Hydro-Québec Les Atriums 870, boul de Maisonneuve est, Montréal, Québec H2L 4S8

Quant aux tendances futures pour évaluer le stress environnemental, nous croyons qu'il y a effectivement intérêt à suivre l'évolution des comportements plutôt que les seuls facteurs létaux en raison de la capacité de plusieurs espèces à modifier leurs réactions physiologiques et à s'adapter à de nouvelles conditions environnementales. Dans ce contexte, Hydro-Québec poursuit présentement des études expérimentales sur le stress thermique, en collaboration avec le groupe de Recherche en Ecologie aquatique de l'UQTR. A titre de renseignement, vous trouverez ci-joint un sommaire des principales réalisations des années 1980 et 1981.

Espérant que ces quelques prévisions vous seront profitables, je vous invite à communiquer directement avec les responsables de ces divers programmes. Il va sans dire que nous apprécierions connaître les conclusions de votre étude.

- Surveillance radiologique:

  M. Serge Trussart, chef de division
  Protection Radiologique des Populations
  Direction Santé et Sécurité
  Hydro-Québec
  Tél: 652-8578

- Surveillance thermique et écophysiologie:

  M. Gaétan Guertin
  Chef de programme des études biophysiques en aménagement
  Ecologie biophysique
  Direction Environnement
  Hydro-Québec
  Tél: 289-6061

Veuillez agréer, Mademoiselle, l'expression de mes sentiments les plus distingués.

Claude Cardinal
Chef du programme d'études générales
Ecologie biophysique
Direction Environnement

CC/lb

p.j.

c.c.: S. Trussart
G. Guertin
D. Granger
L.-P. Roy

Ontario Hydro

Box 1540, Tiverton, Ontario N0G 2T0

July 16, 1982

FILE: 967.141T

Miss C. Létourneau
Research and Development Division
Atomic Energy Control Board
P.O. Box 1046
OTTAWA, Ontario

Dear Miss Létourneau:

Radiological Environmental Monitoring Program

A radiological environmental monitoring program is conducted at the BNPD Site to assess the impact on the public as a result of the operation of the nuclear facilities on site.

This program includes sampling of air, water, fish and milk which for this specific location are considered the appropriate pathways for the direct and indirect exposure of man. Attached you will find, in Table 1, a brief summary of our current monitoring practice. As you can see, only two sampling media, fish and milk, can be classified as "biological indicators".

However, a new radiological environmental monitoring program has been developed and recommended for implementation for the BNPD Site. It will result in an expansion of the sampling media chosen for monitoring particularly by the addition of a variety of vegetation. The nature of the land use in the BNPD vicinity determines what vegetation need be monitored; only the vegetation produced for human consumption will be sampled as part of the BNPD Program. Similarly, the choice of appropriate species of fish for sampling is decided by taking into account two factors: one, the species likely to be consumed by the public and two, the species whose living and eating habits render them the worst case for potential uptakes of radioactive material by fish.

It is important to stress that this program is designed to assess the radiological impact on man, and not other animal species in the environment.

011706

Telephone (519) 368-7031

One further point is that we sample biological and physical parameters as indicated in the attached table; chemical parameters are not applicable in this case.

I hope this satisfactorily answers your questions. If you have any further inquiries please do not hesitate to write or call us at 519-368-7031, extension 3147.

Linda Weekes
Health Physicist
BNPD Services Department

LW/kc

Att.

cc: D. Dawson - BNGS'A'
M. Walke - BNGS'A'

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
LA COMMISSION D'ÉNERGIE ÉLECTRIQUE DU NOUVEAU-BRUNSWICK

Pt. Lepreau G.S., P.O. Box 10,
Lepreau, New Brunswick, E0G 2H0

26-1-1:-4-0
C LETOURNEAU

1982-07-06

Carmel Létourneau
Research and Development Division
Atomic Energy Control Board
P.O. Box 1046
Ottawa, Ontario
K1P 5S9

Dear Carmel:

In response to your letter of 82-06-16 I am enclosing a copy of a reference document on Environmental Monitoring for the Point Lepreau Generating Station. It describes the radiation monitoring program which has been developed for the environment near Point Lepreau.

You will note in the report that the biological samples include lobster, clams, seafish and dulse (a seaweed which is eaten as a delicacy by the local population). These species were chosen because they are pathways by which radioactivity may reach man through the food chain. They were not chosen because they are especially good biological indicators, however, seaweeds such as dulse are known to have high concentration factors for certain radioactive nuclides such as radioiodine. We did reject many other types of samples because (a) they were not pathways to man (e.g., other types of seaweed) or (b) collection of the samples would have been more harmful to the environment than beneficial in terms of information obtained (e.g., we do not kill seabirds, rabbits, etc.). In some instances other indicators may be preferred over biological indicators. For example, fine silts on the mudflats near our station are known to concentrate fallout radioactivity.

.../2

101107

As for future trends, the methods for monitoring radioactivity in the environment are fairly similar at different utilities and I do not expect many changes in the types of samples collected. Future trends appear to be more in the area of selective radionuclide analysis (e.g., C-14 analysis and gamma spectrometry analysis) rather than in the choice of samples.

I hope this information is of some assistance. Please contact us if you desire further information. Details of the results of our monitoring program may be obtained by calling Dr. John K. Sutherland (506-453-3161).

Yours truly,

EB for JJP

John J. Paciga
Station Health Physicist

JJP/cep

cc J.K. Sutherland
Roland Krause - Information Services

3 4-5-0-2
C LETOURNEAU

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR
DEPARTMENT OF ENVIRONMENT

ST. JOHN'S

In Reply Please Quote
File Ref. No.

1982 07 20

Ms. Carmel Letourneau
Research and Development Division
Atomic Energy Control Board
P. O. Box 1046
Ottawa, ON
K1P 5S9

Dear Ms. Letourneau:

Regarding your request for information on our use of biological indicators, please be advised that at present no such use is being carried out nor is any planned for the immediate future.

As far as trends concerning chemical or biological methods is concerned, any comments at this time would be premature.

Yours truly,

David H. Barnes

David H. Barnes, Ph.D.
Director
Environmental Assessment

pt

001795

NOVA SCOTIA
DEPARTMENT
OF THE
ENVIRONMENT

P.O. Box 2107 Halifax, Nova Scotia B3J 3B7

Your File:

Our File: 200-A8

34-5-0-0

July 30, 1982

C LETOURNEAU

Ms. Carmel Letourneau
Research and Development Division
Atomic Energy Control Board
P.O. Box 1046
Ottawa, Canada
K1P 5S9

Dear Ms. Letourneau:

In response to your letter of June 16, 1982, I am able to provide the following information.

With respect to the use of biological indicators to measure environmental stress, I am familiar with only one case in Nova Scotia. The program consisted of using the distribution of marine plants as an indicator of the distribution of effluent from a pulp and paper mill. Detailed information is available from Dr. Klaus Hellenbrand, Nova Scotia Research Foundation, Dartmouth, Nova Scotia.

The Nova Scotia Department of the Environment seldom uses biological indicators as a measure of environmental stress. The main reason for this relates to the difficulties in determining the actual "stress factors" to which the organism is responding. In a single parameter situation, "dose" or amount of stress can be directly determined by the response of the organism. However, environmental stress seldom ever appears as the result of a single parameter. The problem then becomes one of determining which parameter is causing the response or are several factors operating in an additive factor or are they operating in a synergistic fashion. Returning full circle on the argument, the question then becomes one of determining which environmental parameter requires alteration.

Indicator species are obviously a valuable tool in a "watch dog" capacity. They are certainly effective as an early warning system.

../../2

00237

I trust that the above information is of assistance in the preparation of your report.

Yours truly,

D. L. Waugh

D. L. Waugh, Ph.D.
Chief Environmental Development

DLW/dm

UTAH STATE UNIVERSITY LOGAN, UTAH 84322
COLLEGE OF AGRICULTURE

DEPARTMENT OF
PLANT SCIENCE
UMC 48

34-5-0-0
C LETOURNEAU

27 September 1982

Dr. Carmel Letourneau
Research and Development Division
Atomic Energy Control Board
P.O. Box 1046
Ottawa, Canada K1P 5S9

Dear Dr. Letourneau:

Re: Your letter of inquiry concerning "Biological indicators" for monitoring environmental stress, we are enclosing two reprints from our work. Our research dealt with monitoring low-level ionizing radiation from soil obtained from uranium mill tailings. We feel that this species is sufficiently sensitive to also be used to monitor the mutagenic affects of various industrial chemicals.

Two other plants that are of value as biological monitors are lichens and Arabidopsis. Lichens are known to be very sensitive to air pollution, especially SO_2 and NO_2, while Arabidopsis, because of its low chromosome number has been used in some ionizing radiation studies.

I hope that these suggestions and references will be of some help to you. With best wishes, we remain.

Sincerely yours,

WF Campbell

William F. Campbell/Eric A. Rechel
Prof. Crop Physiol./Res. Assoc.

WFC:kbm

000233

Gouvernement du Québec
Ministère de l'Environnement
**Direction générale
des inventaires et de
la recherche**

34-S-C-1
C LETOURNEAU

Québec, le 19 juillet 1982

Monsieur Carmel Létourneau
Direction de la recherche et
du développement
Commission de contrôle
de l'énergie atomique
C. P. 1046
Ottawa
Canada
K1P 5S9

Monsieur,

Votre lettre du 16 juin dernier, adressée au Ministère de l'environnement du Québec, m'a été transmise car le ministère m'a donné le mandat et la responsabilité de l'évaluation de la toxicité au moyen d'intégrateurs biologiques, en tant que responsable de la Division biologie, à la Direction des laboratoires.

Présentement, nous utilisons 3 types d'indicateurs biologiques ayant des sensibilités différentes, que l'on estime donner des résultats complémentaires et permettant d'interpréter les risques possibles aux divers niveaux trophiques. Le plus sensible de ces trois tests, qui est en même temps le test le plus sensible actuellement connu pour l'évaluation de la toxicité, à l'intérieur d'un délai raisonnable, est basé sur l'inhibition des mécanismes de division cellulaire de l'algue unicellulaire *Selenastrum capricornutum*. Le principe de ce test peut s'appliquer sur des échantillons d'eau salée, en substituant l'organisme par une espèce d'algue marine, de même qu'il pourrait constituer un test d'une grande valeur dans le domaine qui vous concerne, soit l'impact des rejets de matériel radioactif. Les deux autres tests sont l'inhibition de la mobilité de la daphnie *Daphnia magna* et le Microtox® de beckman, qui utilise une bactérie bioluminescente. La sensibilité de ces deux derniers tests est comparable et se situe assez près de la sensibilité de la truite arc-en-ciel. Cependant, de façon générale, le Microtox® est plus sensible aux substances organiques, alors que la daphnie est plus sensible aux substances inorganiques, faisant de ces deux tests

des tests complémentaires. La combinaison de ces trois tests permet donc de couvrir un spectre de détection assez large de la toxicité. De plus, le volume d'échantillon nécessaire pour réaliser ces trois tests n'est que de 1 litre et leur coût total est inférieur d'au moins 5 fois à celui utilisant la truite arc-en-ciel.

Au ministère, nous utilisons régulièrement les tests avec algues et daphnies depuis 4 ans et le Microtox® depuis 2 ans. Ces tests sont parfois utilisés dans des causes légales, puisque l'article 20 de la "Loi de la qualité de l'environnement" permet l'utilisation de divers types de tests pour démontrer la susceptibilité de causer des dommages à l'environnement. Présentement, le ministère envisage d'inclure ces tests spécifiques dans une directive sur la disposition des déchets dangereux.

Vous trouverez ci-joint un tiré-à-part expliquant le principe du bioessai avec l'algue *Selenastrum capricornutum*, de même qu'une copie de la méthode française utilisant les daphnies et de celle du Microtox® de Beckman.

Espérant le tout à votre satisfaction, veuillez agréer, monsieur, l'expression de mes sentiments les meilleurs.

GJ/ca

Gérald Joubert
Responsable, division biologie,
Laboratoire de Québec

et "Chairman" du "Intergovernmental
Aquatic Toxicity Group"

34-5-0-1

C LETOURNEAU

Alberta
ENVIRONMENT
Research Management Division

14th Floor, Standard Life Centre, 10405 Jasper Avenue, Edmonton, Alberta, Canada T5J 3N4 403/427-3943

August 10, 1982

Carmel Létourneau
Research & Development Division
Atomic Energy Control Board
Ottawa, ON K1P 5S9

Dear Ms. Letourneau:

In response to your request for information on the validity of using "biological indicators for monitoring environmental stress", enclosed please find a copy of the list of publications produced by the Research Management Division of Alberta Environment.

I have indicated in red, reports which may address your questions relative to biological indicators. These reports are available from the following libraries in your area:

(1) Departmental Library
Acquisitions Section
Environment Canada
Ottawa, ON K1A 1C7

(2) Canadian Acquisitions Division
Government Documents
National Library of Canada
395 Wellington Street
Ottawa, ON K1A 0N4

With reference to the remainder of your questions relative to biological indicators and monitoring techniques inuse in this province, Alberta Environment is actively pursuing the development of biological monitoring techniques in its routine monitoring programs. However biological monitoring is considered only one component of an ecosystem monitoring approach which includes concurrent physical and chemical measurements of environmental parameters. The selection of the biological indicators to be utilized in the program has not been restricted to a particular species but rather a combination of basic biological processes (e.g., nutrient fluxes, nutrient pools, etc.) together with species abundance, diversity and community structure.

In addressing your final question regarding the preference for methods in the future, I would add that Alberta Environment will stress ecosystem structure and function when assessing the impacts of contaminants on the environment.

(01317

I hope these comments have addressed your concerns and if I can be of any further assistance, please do not hesitate to contact me.

Yours truly,

B.A. Munson
Research Manager

BAM/mr
Attach.

cc J. Shah
C. Staddon-Communications

Environment Canada Environnement Canada

40-1-C
C LÉTOURNEAU

Your file Votre référence

Our file Notre référence

OTTAWA (Ontario)
K1A 0H3

June 23, 1982

Miss Carmel Lêtourneau
Research and Development Division
Atomic Energy Control Board
P.O. Box 1046
Ottawa, Ontario
K1P 5S9

Dear Miss Lêtourneau:

I am writing in reply to your June 16 letter about biological indicators of environmental quality.

Yes wildlife especially birds and fish, are being used as biological indicators. The Canadian Wildlife Service has been monitoring herring gull colonies on the Great Lakes since the early '70s for concentrations of toxic chemicals. Because of their nesting and feeding habits, their place in the food chain and their choice of foods herring gulls and other bird species are valuable tools in the assessment of the spread of contaminants.

I have enclosed four technical papers published by the Canadian Wildlife Service which describe some of the work in this area.

For further information please contact Dr. David Peakall, Chief, Toxicology Division, Canadian Wildlife Service, 997-2780.

Yours truly,

Wayne Roddick

H.W. Roddick
Communications Advisor (Wildlife)
Information Directorate

001902

Encl.

Canada

In order to conserve energy and resources, this paper contains 45 per cent recycled post-consumer fibre

A déjà mis de conserver énergie et ressources, ce papier contient 45 pour cent de fibres recyclées

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
RESEARCH AND DEVELOPMENT

JUL 16 1982

Carmel Letourneau
Research and Development Division
Atomic Energy Control Board
P.O. Box 1046
Ottawa, Canada
K1P 5S9

Dear Ms. Letourneau,

Thank you for your letter of inquiry dated June 16, 1982 (your file reference 34-5-0-0). Your summer assignment of preparing a report on the possibility and validity of using biological indicators for monitoring "environmental stress" is indeed a challenging one. The U.S. Environmental Protection Agency (USEPA) uses biotic response as a part of pollution assessments, in the form of a hierarchy of tier tests. The issue is rather complicated, and our decision to use whole organism responses as part of our assessment depends upon what questions we wish to answer.

For our agency, we look for biotic injury (or lack of it) with the eventual goal of regulating the released (or applied) pollutant levels. For this work, our scientists make a judgement as to which organisms or populations should be used for test exposures. To reduce the complexity of choice, we select organisms which are easily cultured, and which are ecologically and/or economically representative of the biota at risk.

Our current work is based upon laboratory and microcosm tests, supported by field observations. I have included some U.S. EPA publications on procedures and test organisms for your information. These procedures support our ocean and fate monitoring program under the Clean Water Act.

Regarding trends of future methods, our strategy is to verify our laboratory data with regard to its accuracy to actual field situations and to rely upon a variety of tests to indicate hazard levels. We are also developing predictive mathematical models for defining exposure of pollutants to biota. The exposure data are then evaluated in the light of hazard information to obtain eventual environmental risk due to pollutants.

101733

I hope this information will be useful in your report. Thanks for writing us about these important questions.

Very truly yours,

Courtney Riordan
Acting Assistant Administrator
for Research and Development

Enclosure

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

34-5-0-0

C LETOURNEAU

OCT 6 1982

Atomic Energy Control Board
Research & Development Division
Attn: Carmel Letourneau
P. O. Box 1046
Ottawa, Canada K1P 5S9

Gentlemen:

Your letter of June 16 (34-5-0-0) has caused us to reflect on our experience using biological indicators for monitoring environmental stress. We have a substantial history of biological monitoring in the vicinity of licensed nuclear power plants, which at some sites has been very extensive. The essence of the results of our experience has been that stresses attributable to power plant operation are not being shown by the monitoring programs.

We make a distinction between non-radiological and radiological monitoring, generally including radiological monitoring with safety programs and non-radiological monitoring with environmental programs. Our regulations for radiological monitoring require licensees to establish an appropriate surveillance and monitoring program to provide data on measurable levels of radiation and radioactive materials in the environment to evaluate the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure. This usually involves collection of specimens of one recreationally important and one commercially important fish species two to four times per year for radionuclide analysis.

Non-radiological monitoring programs have shown greater diversity because their objectives have been to detect changes in distribution and abundance of aquatic organisms. The environmental review which precedes licensing of a station focuses on important species (which may be either recreationally or commercially important, endangered locally or nationally, or merely an important organism to the local aquatic ecosystem). Consequently, the operational monitoring programs have tended to focus on representative important species as "indicator" organisms. As I indicated this has not been particularly effective in establishing changes associable with power plant operation. There is some feeling that present-day biological monitoring and evaluation techniques are not sensitive enough to detect changes. Others hold that indeed the projects are not inducing detectable changes.

Reports evaluating our monitoring programs could be made available if your agency would like. These reports conclude, in general, that attempts to document impact to fish populations on the basis of changes in population abundance will be unfruitful with state-of-the-art monitoring, with the exception of catastrophic impacts which would be obvious without a sophisticated monitoring program. Also, evaluations of theoretical (mathematical) ecosystem models as a tool for impact assessments indicate that input data needed for model validation are not available and cannot be obtained due to the noted problem with state-of-the-art monitoring.

8004131

Instead of examining organisms, you may wish to consider the habitat evaluation approach as being promoted by the U.S. Fish and Wildlife Service (FWS). This approach defines critical habitat needs of fish and wildlife and assesses the effect of alteration and/or loss of habitat values without attempting to "count" organisms. In a sense, the habitat unit in FWS's Habitat Evaluation Procedures is a "biological indicator." You should contact FWS's Division of Ecological Services for more information.

With regard to your question on trends, we find that well sited and designed nuclear stations will generally not have measurable impacts on the environment and thus the emphasis will be on control of releases to design values rather than on far field monitoring.

If AECB would be interested in our environmental reviews for projects on the Great Lakes, or for that matter elsewhere in the country, reports can be made available. An exchange of information and ideas between our environmental scientists may be beneficial to both of our agencies.

Sincerely,

Joseph D. Lafleur, Jr.
Deputy Director
Office of International Programs